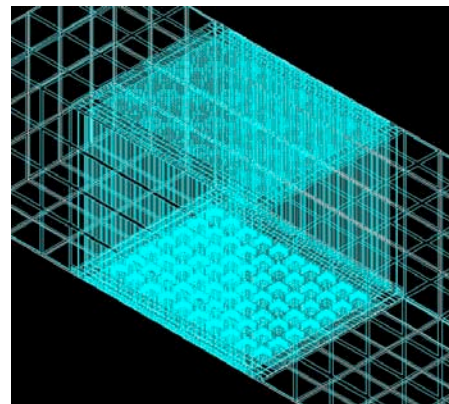
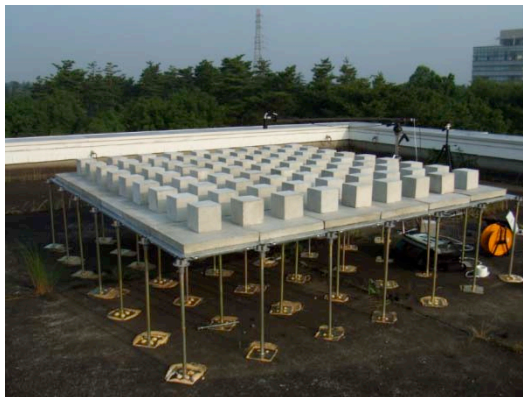


# Study on the characteristics of solar radiation in the geometrically complex urban spaces by using a spectroradiometer

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Daisuke Itoh, BRI

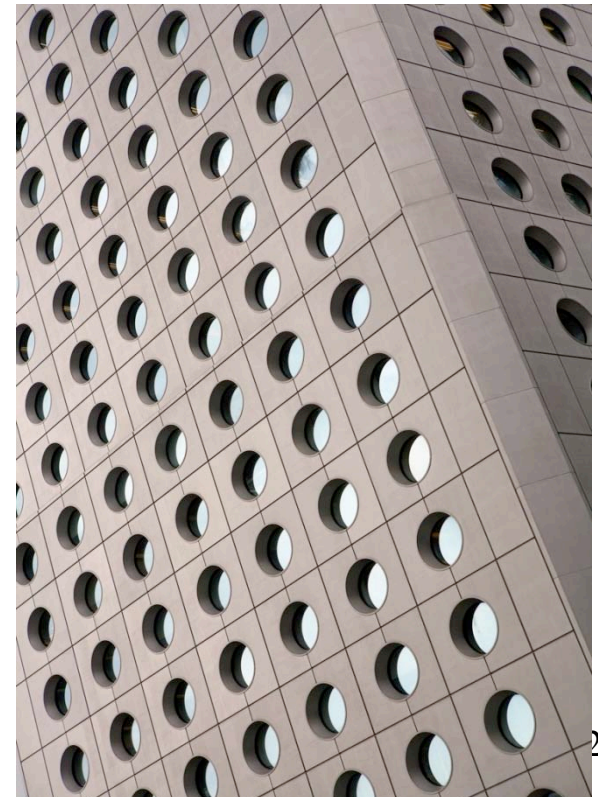


## Research purpose

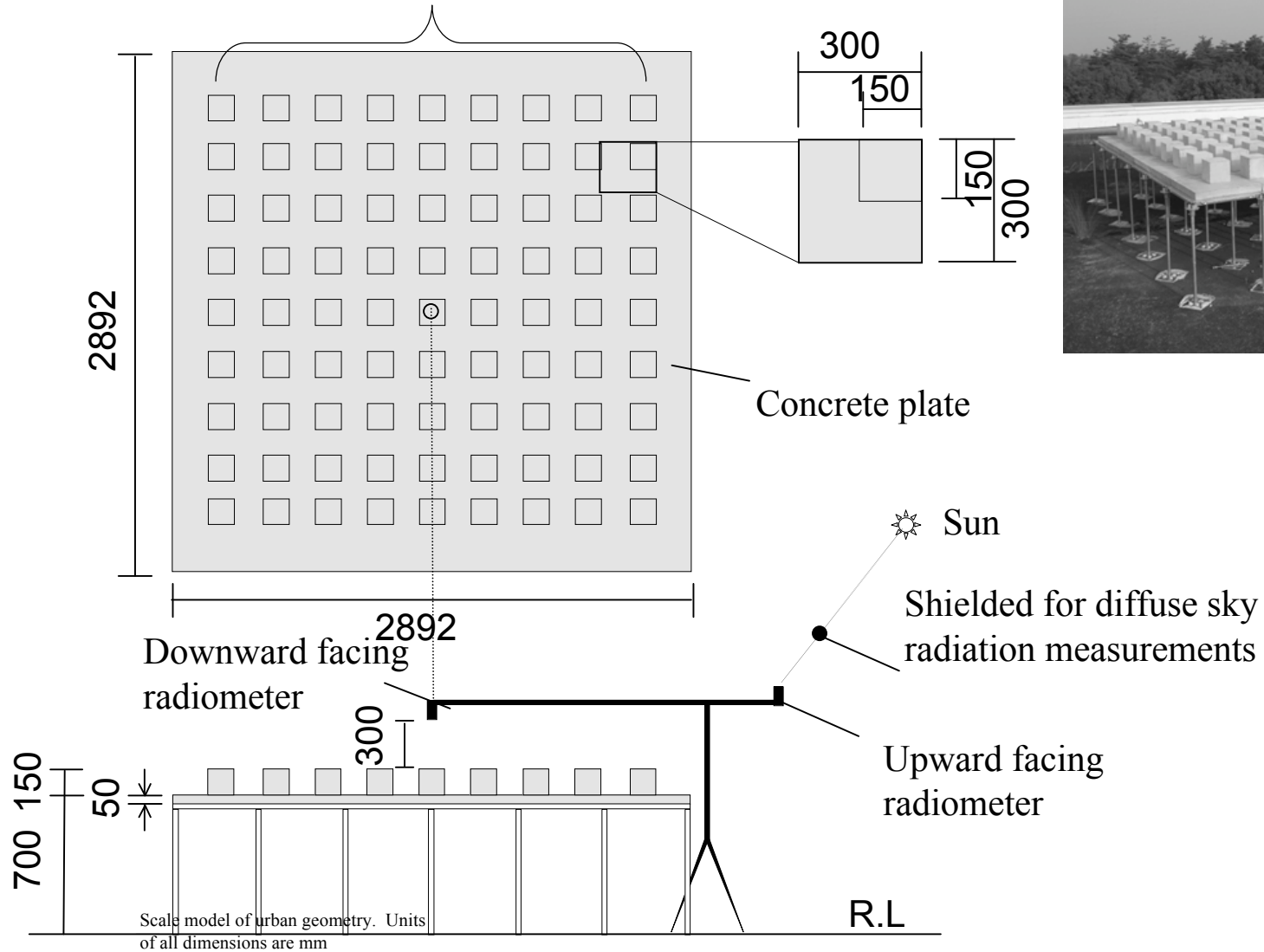
The surface albedo is considered an essential factor for investigating the urban heat budget. Increased albedo of the urban surface curtails the heat storage of buildings and roads, and reduces sensible heat transfer from the urban surface to the urban atmosphere.

In recent years, various products have been developed to enhance solar reflectance so that heat island effects are mitigated and air-conditioning cooling loads are reduced. Such products include high reflectance paints (Fujimoto et al. 2006), high-performance glass (Ichinose et al. 2004), and window films (Ashie et al. 2008).

**Given this background, the present study investigates the spectral albedo with the use of scale model experiments and numerical computations.**



81 regularly-arrayed concrete blocks (150 x 150 x 150)



View of scale model experiment and measurements



Items	Specifications
Spectral range	350-2500nm
Angle of measurement	180°※1
Spectral accuracy	±1nm
Detector and spectral resolution *2	350-1000nm : 512 element Si photodiode array(3nm) 1000-1800nm : TE cool, gradedindex InGaAs(10nm) 1800-2500nm : photodiodes(10nm)

※1 When the all sky adaptor is attached.

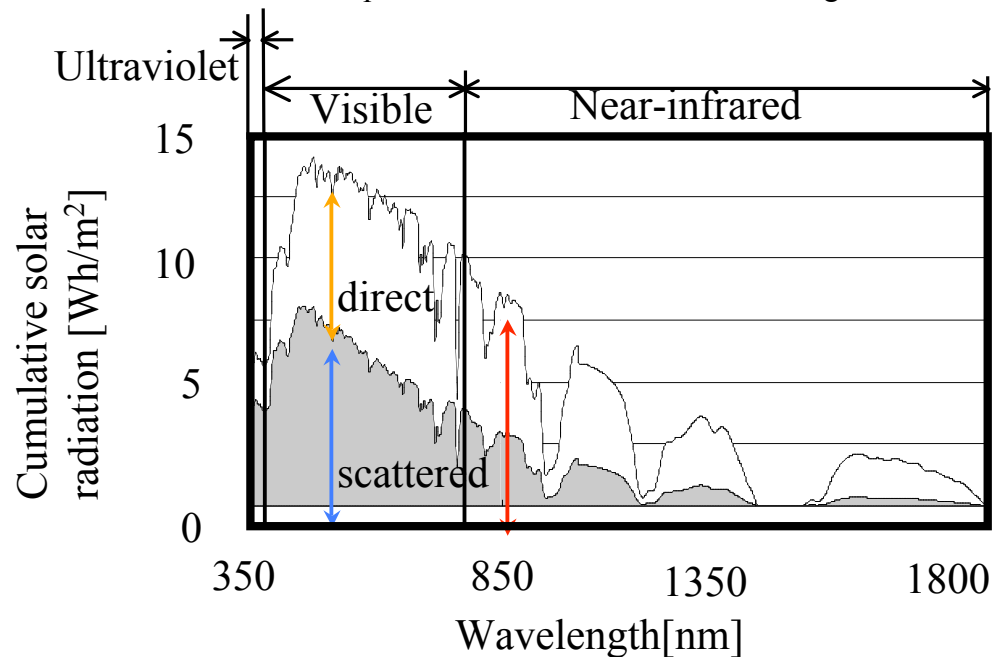
※2 Numerical values in parentheses indicate spectral resolutions.

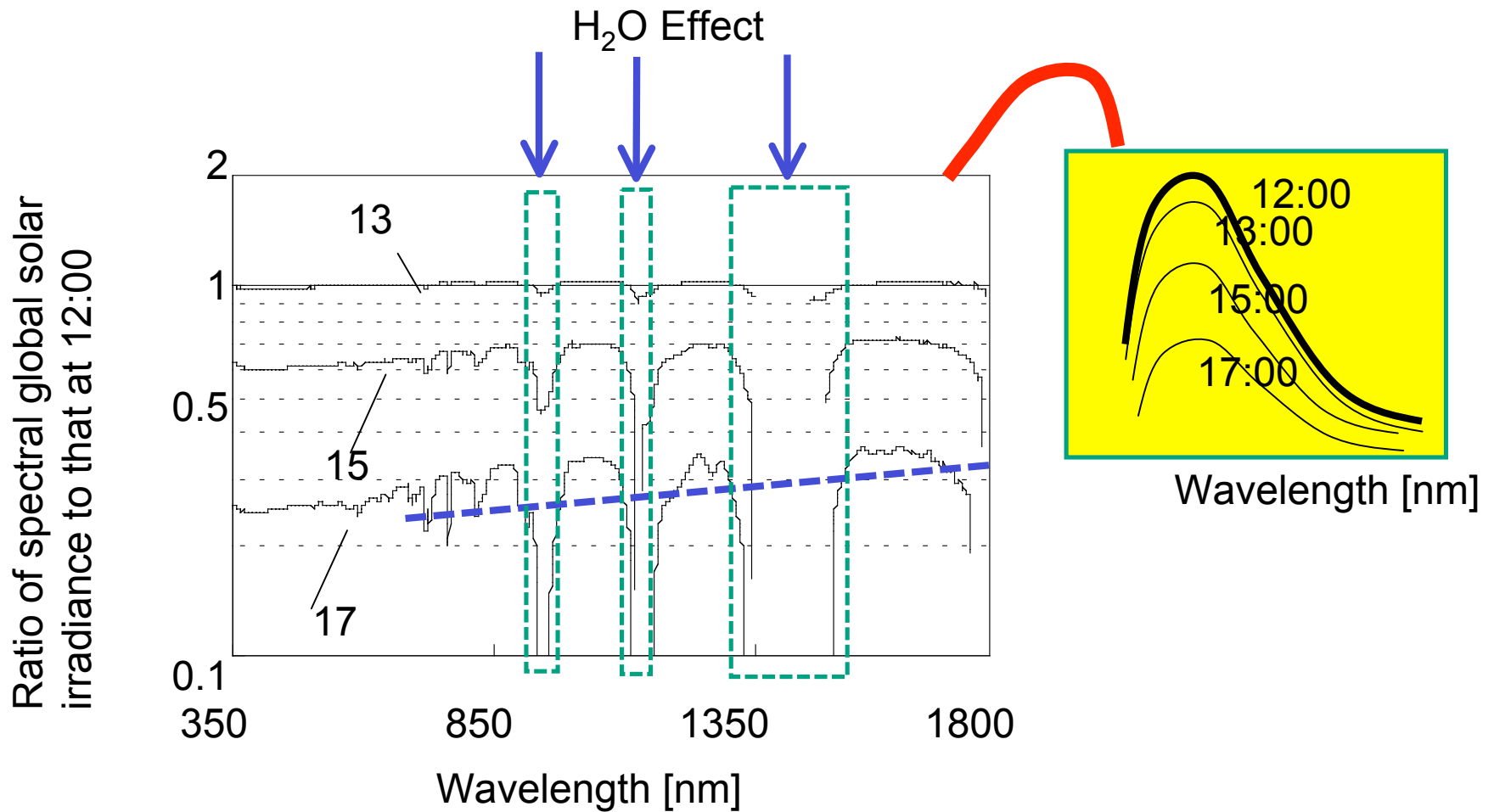
**Spectral radiometer used for measurements**

## Cumulative solar radiation on the day of the experiment (July 12, 2008)

Wave length regions [nm]	Horizontal direct insolation[Wh/m <sup>2</sup> ]	Diffuse solar irradiance [Wh/m <sup>2</sup> ]	Global solar irradiance [Wh/m <sup>2</sup> ]
Ultraviolet region 350~380	52 (0.7)	120 (1.6)	171 (2.2)
Visible region 380~780	2280 (29.6)	2271 (29.5)	4552 (59.0)
Near-infrared region 780~2200	2182 (28.3)	805 (10.4)	2987 (38.7)
All wavelength 350~2200	4514 (58.5)	3196 (41.5)	7710 (100)

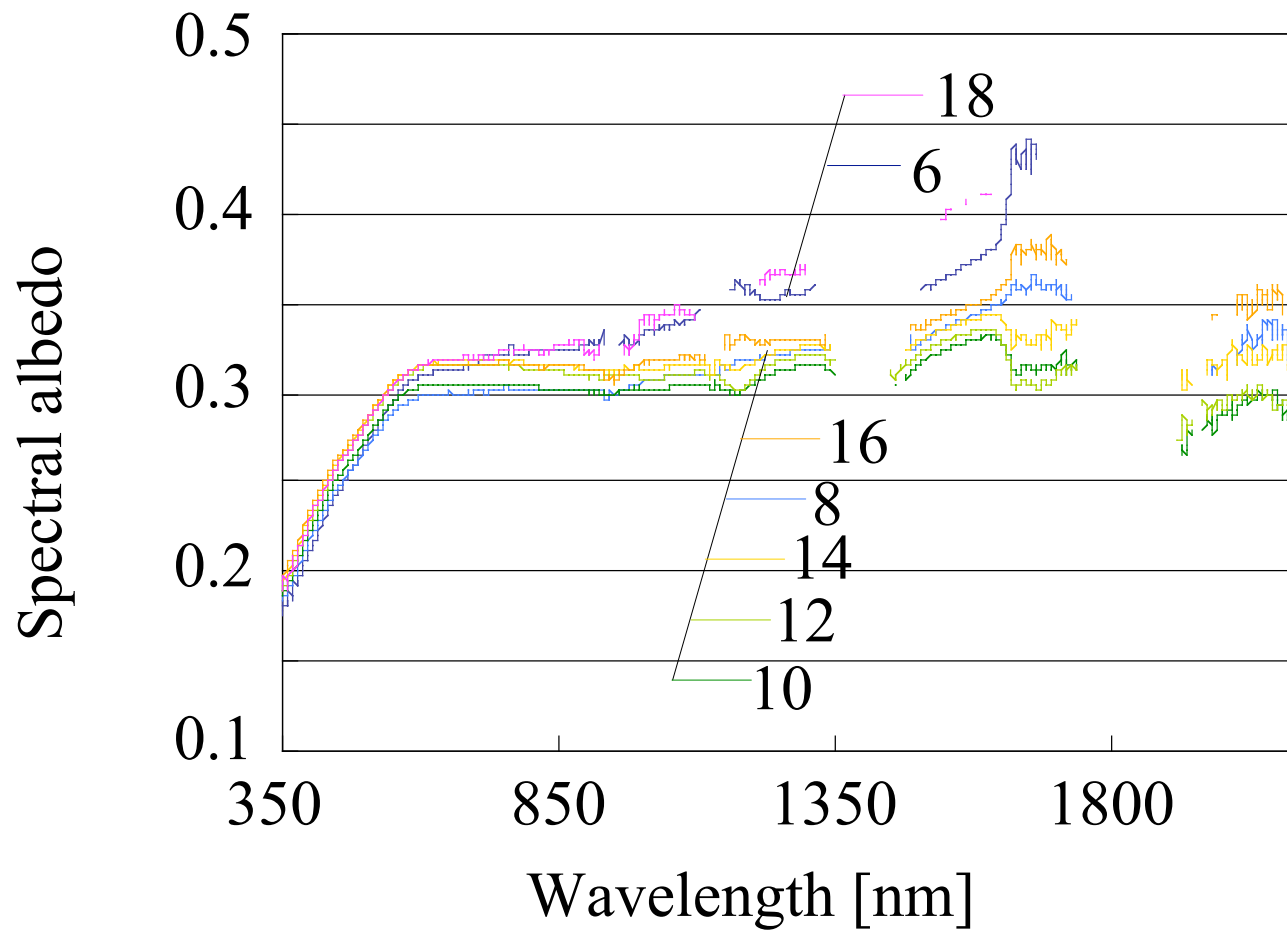
Values in parentheses indicate the ratio to the global solar radiation from all wavelength[%]





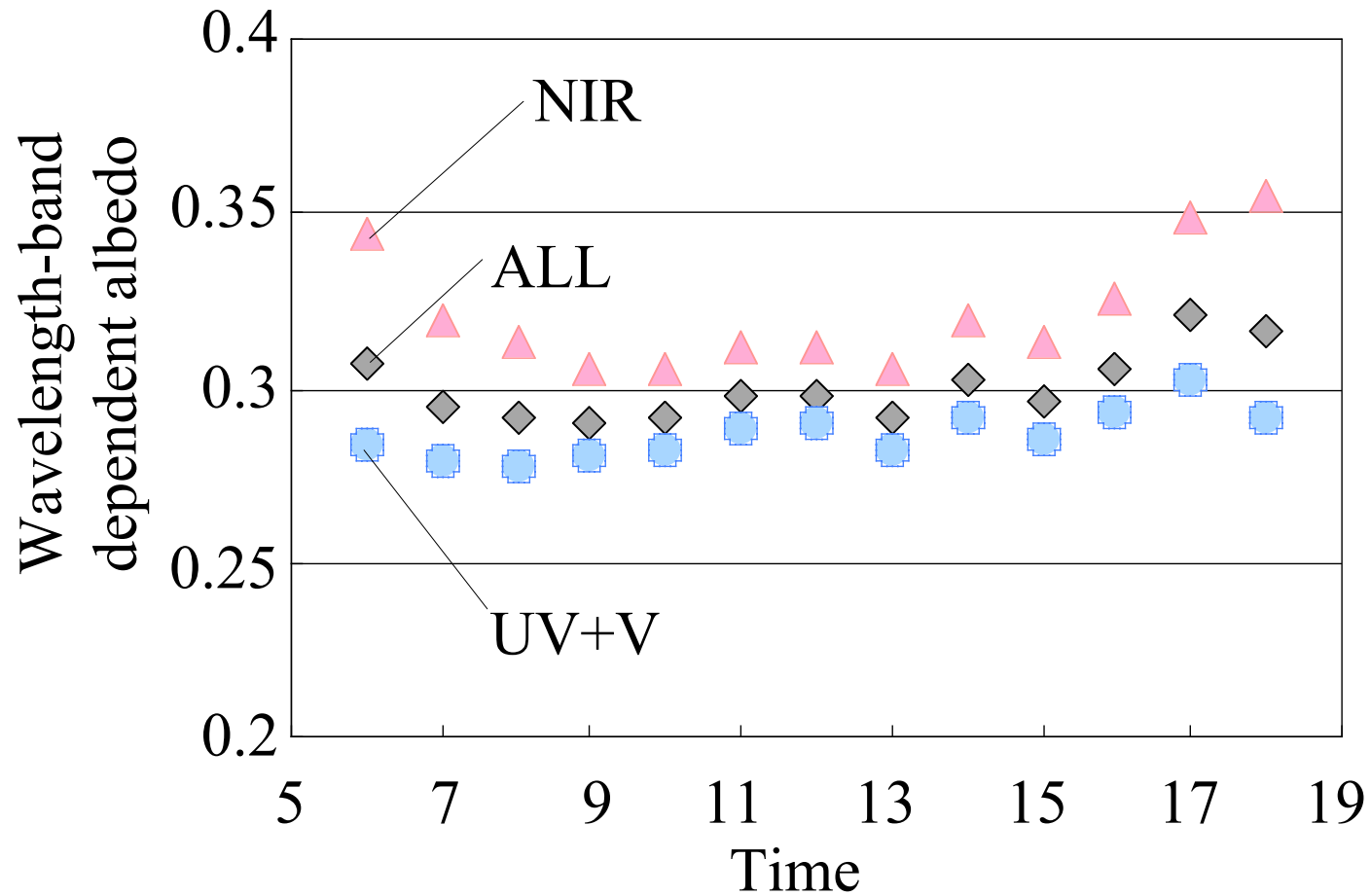
Ratio of spectral global solar irradiance at 13:00, 15:00 and 17:00 to that at 12:00 on July 12, 2008 (numerical labels on the figure indicate time).





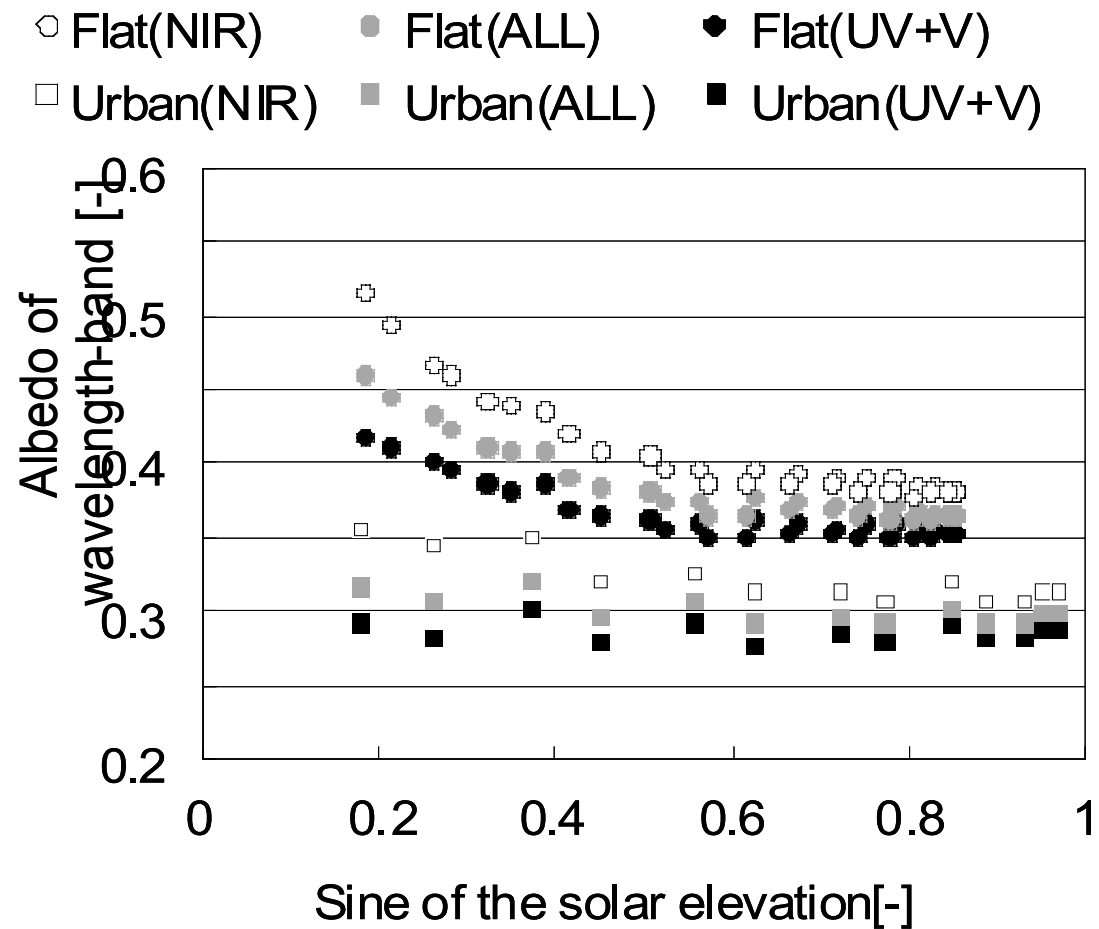
## Spectral albedo of urban surface

(July 12, 2008; numerical values on the figure indicate the time of day)<sub>7</sub>



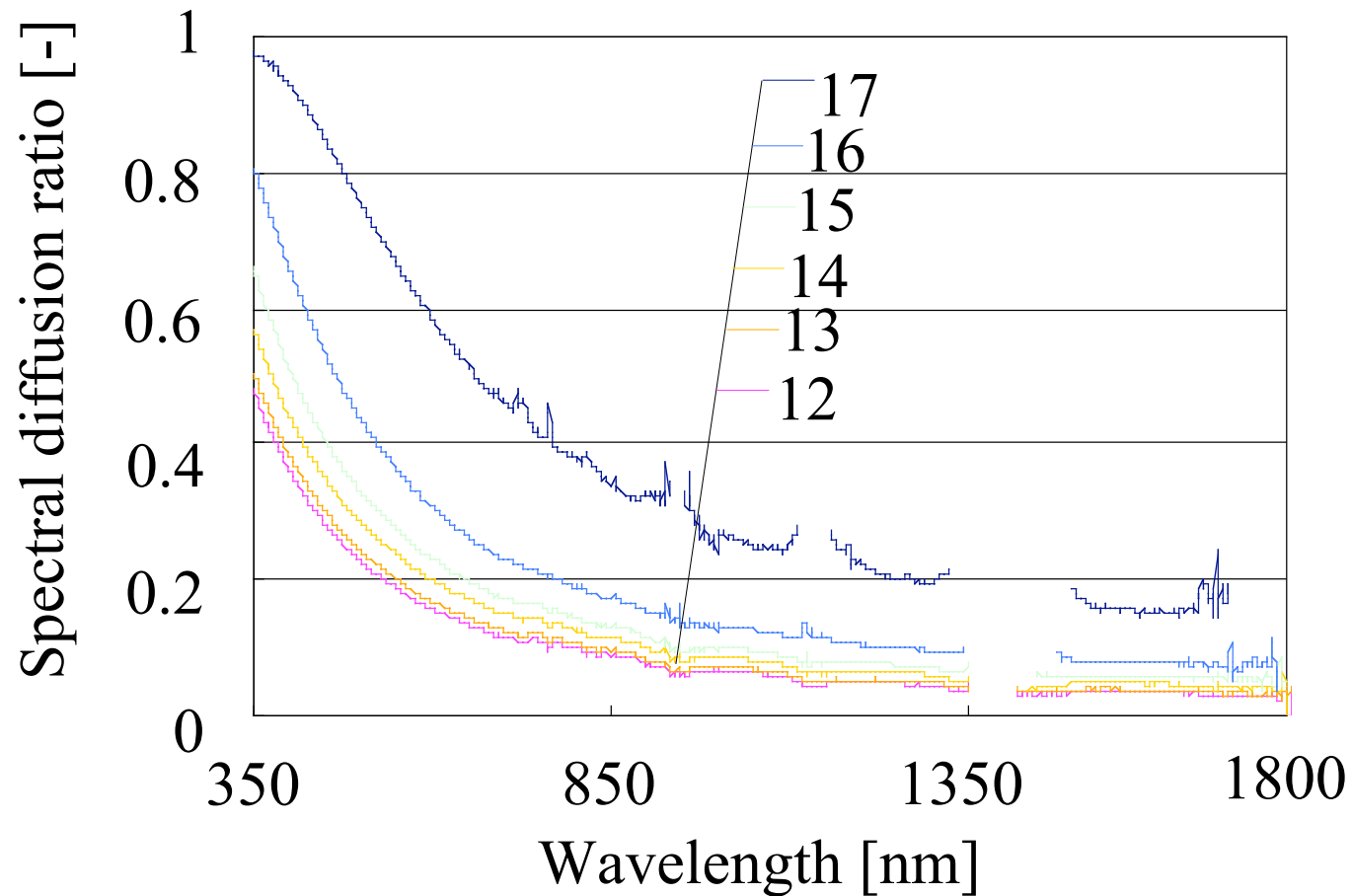
Wavelength-band dependent albedos for the urban geometry (July 12, 2008)



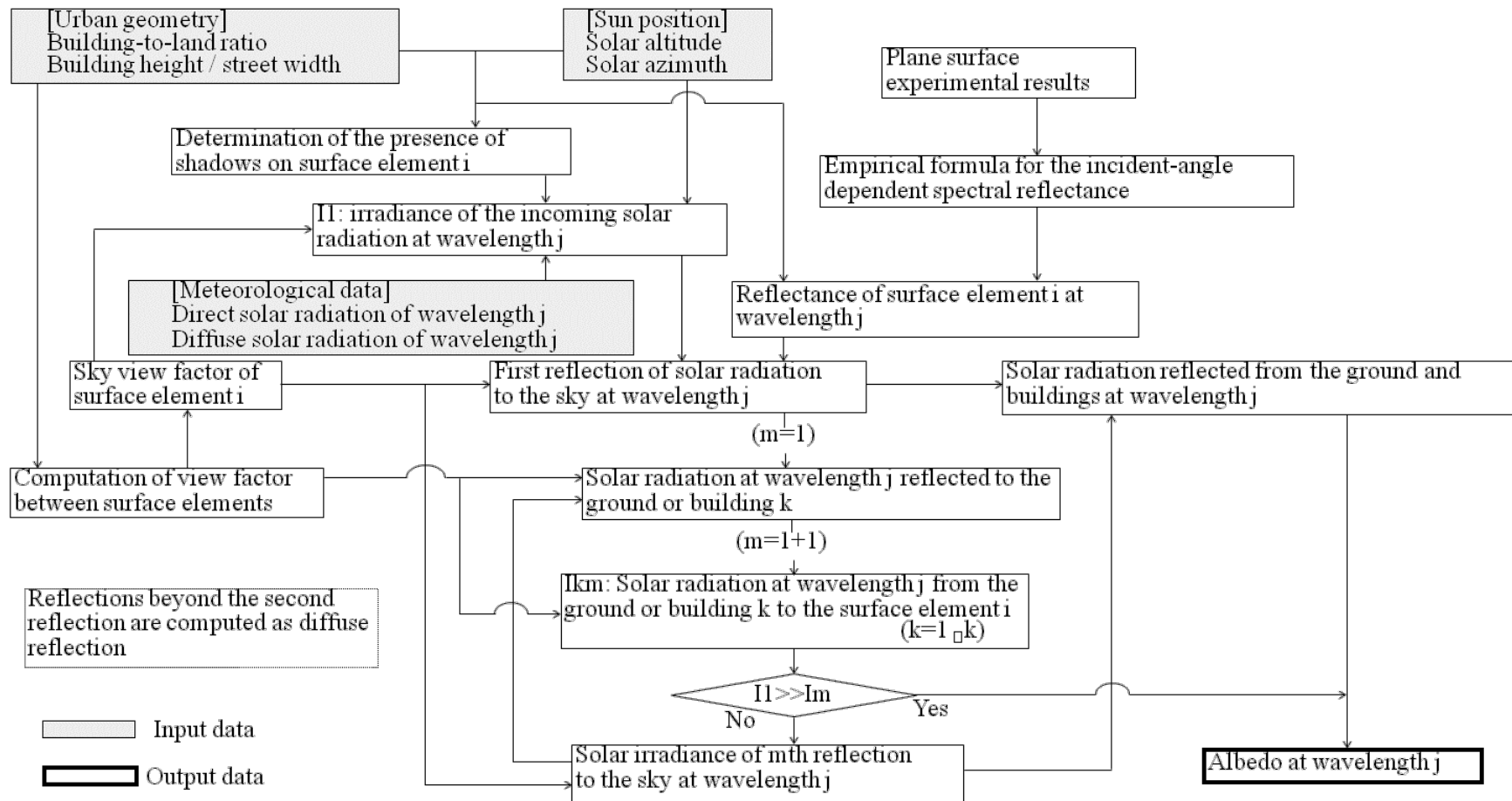


**Comparison of wavelength-band dependent albedo between flat and urban surfaces**

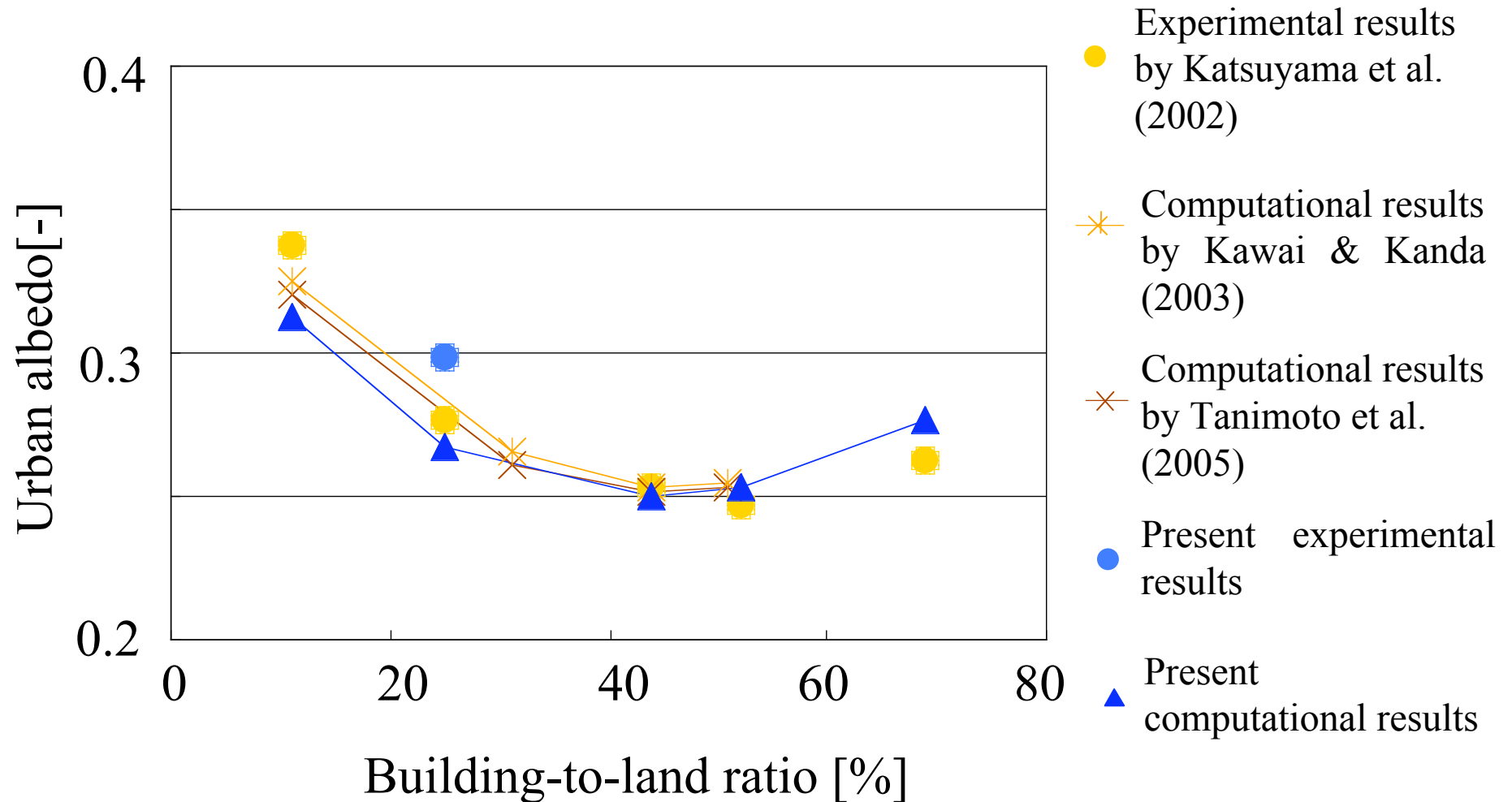
Diffusion ratio=diffusion radiation/global radiation



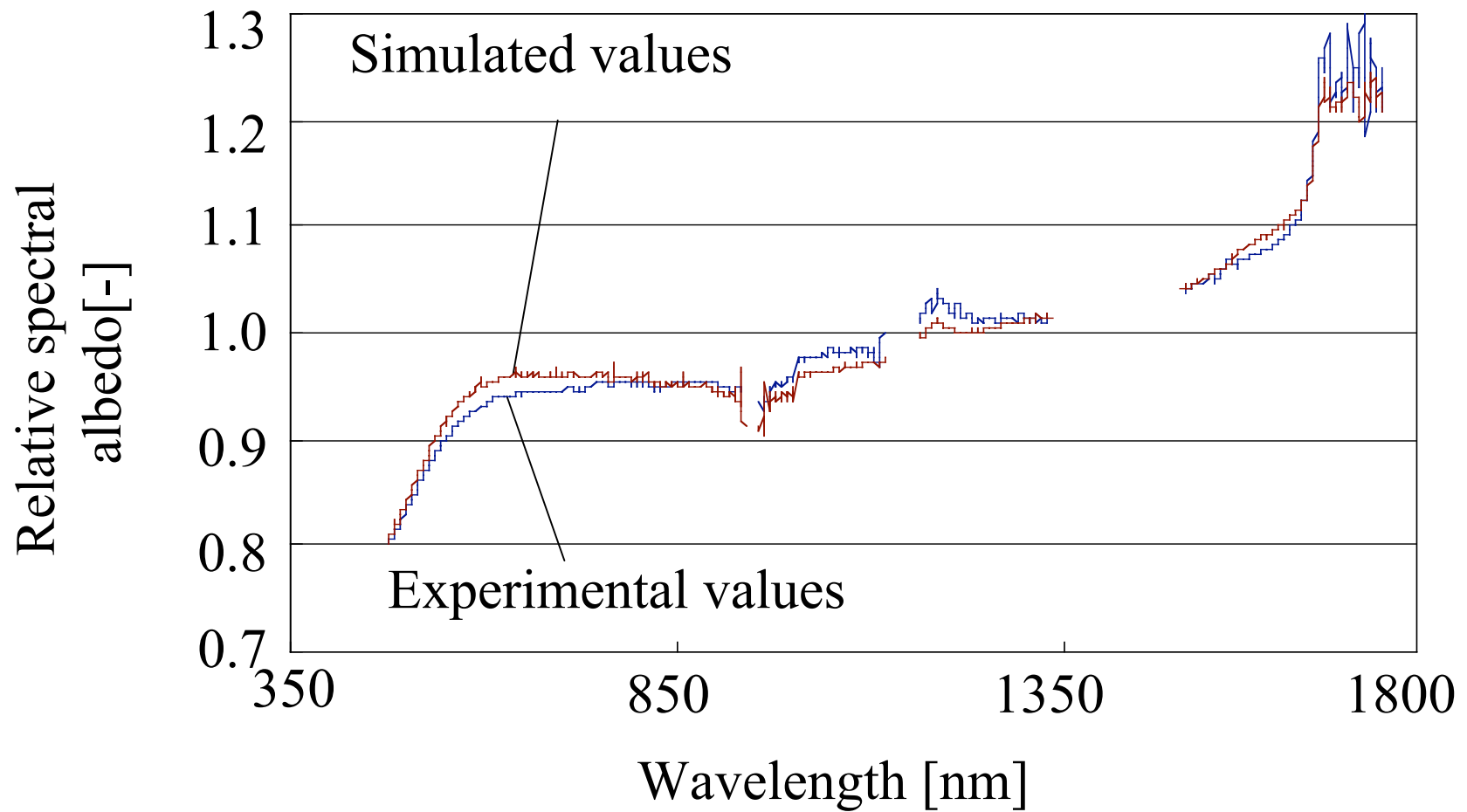
Hourly values of the diffuse spectral ratio  
(September 9, 2009)



## Flowchart of calculations for spectral radiation in urban geometries



Comparisons of the urban albedos calculated from the scale model experiment and simulation to those from previous studies



Relative spectral albedo  
(17:00 on July 12, 2009)

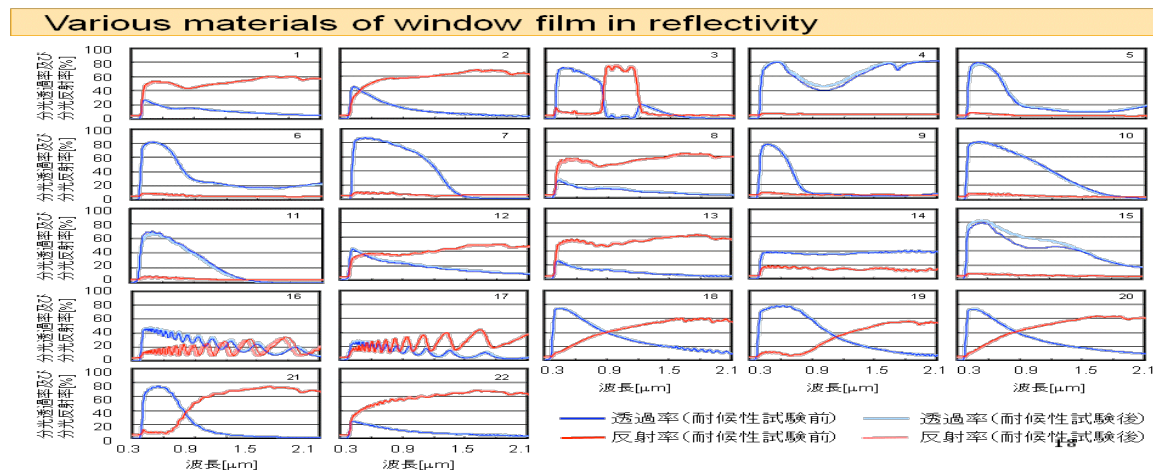
# Conclusion

A scale model experiment was conducted to investigate the urban spectral albedo. The findings from the present study are summarized below:

- 1) According to the scale model experiment, the value of the urban spectral albedo was large in the near-infrared region. The value became particularly large in hours with low solar elevation.
- 2) Compared to the albedo of a flat surface, the values of the urban spectral albedo were small both in the ultraviolet-visual and the near-infrared regions. This result confirms the effect of solar trapping due to multiple reflections, which was identified in previous studies, even for the albedo averaged over wavelength bands smaller than the entire spectrum.
- 3) The experimental data showed that daytime variation of the urban spectral albedo in the ultraviolet-visual region was small. The diffuse spectral ratio was suggested as one reason to explain this observation.

4) The results from the spectral radiation model for various land-to-building ratios agreed well with those from the scale model and previous studies. Furthermore, the spectral radiation model successfully reproduced the distribution of the relative spectral albedo that was observed in the scale model experiment.

The present study suggests the importance of investigations on the spectral characteristics of the high-albedo products on the market and on the application conditions of spectrally selective building materials in the future. With the results of such investigations, simulations of the spectral albedo in conditions similar to the actual environment are necessary.



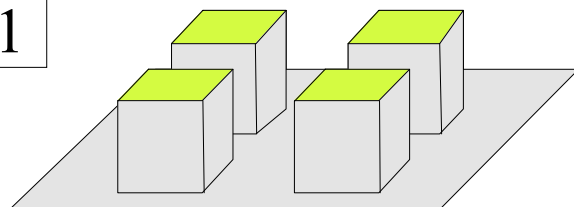


# Thank you for attention

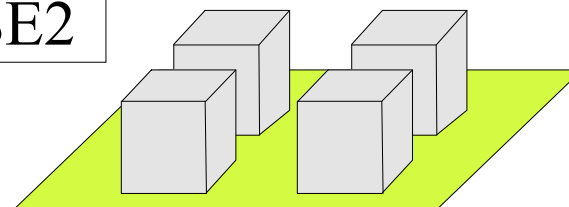


# Case study

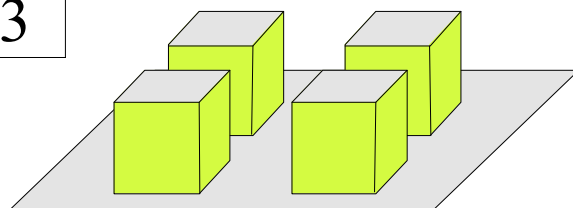
CASE1



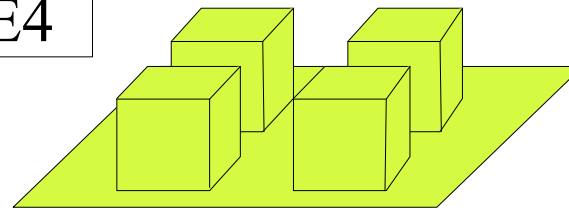
CASE2



CASE3



CASE4



Ordinary materials



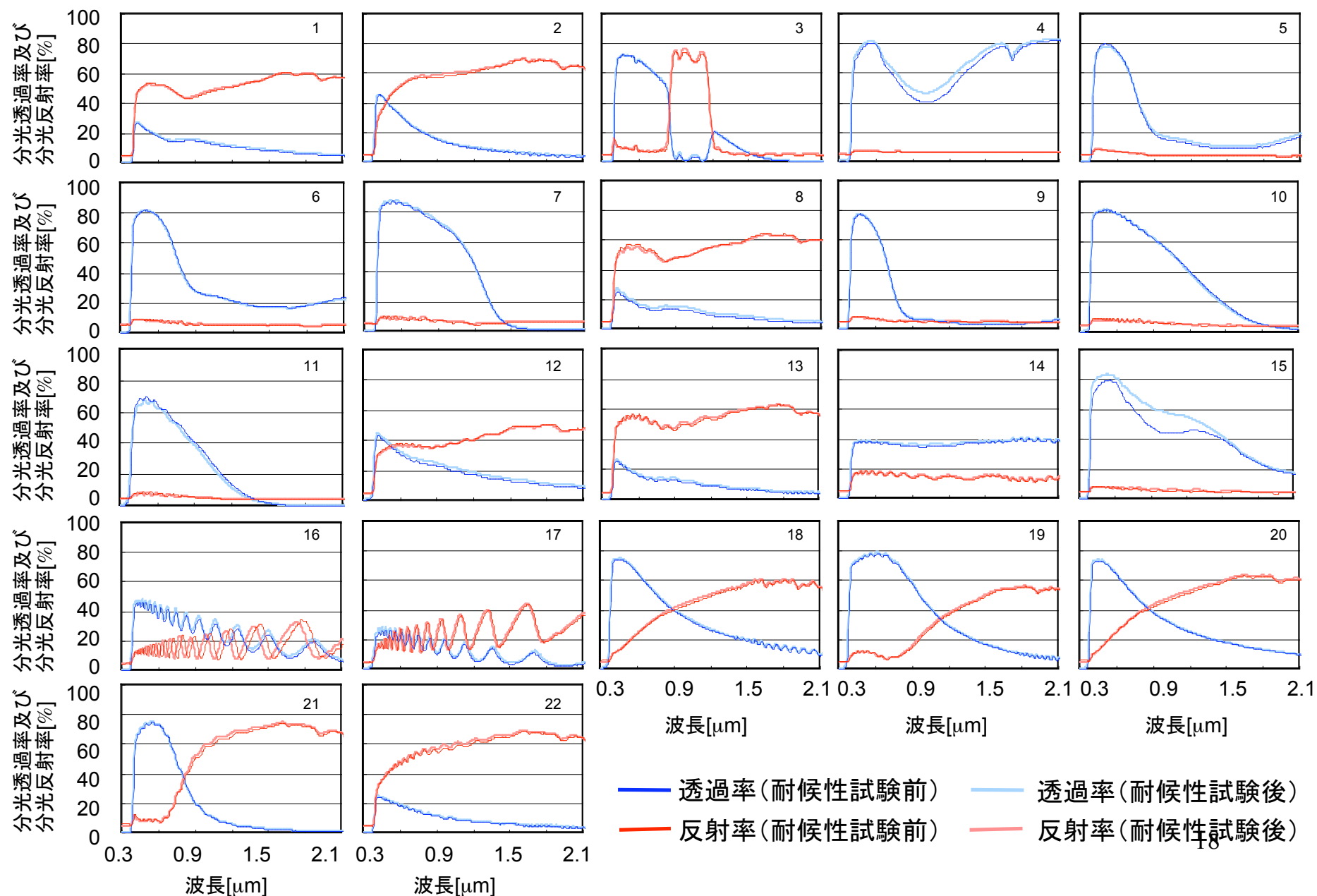
Spectrally selective materials

Solar altitude [deg] <sup>*1</sup>		22.1		
Solar azimuth [deg] <sup>*1</sup>		99.2		
Building-to-land ratio [%]		12.5	25.0	50.0
Ratio of road width to building height [-] <sup>*2</sup>		1.82	1.00	0.414
Ratio of diffuse radiation[-] <sup>*1</sup>	Ultraviolet-visible region	0.679		
	Near-infrared region	0.305		
Spectral-band radiation ratio <sup>*1</sup>	Ultraviolet-visible region:	0.605 : 0.395		
	Near-infrared region			

<sup>\*1</sup> Based on the data from 17:00

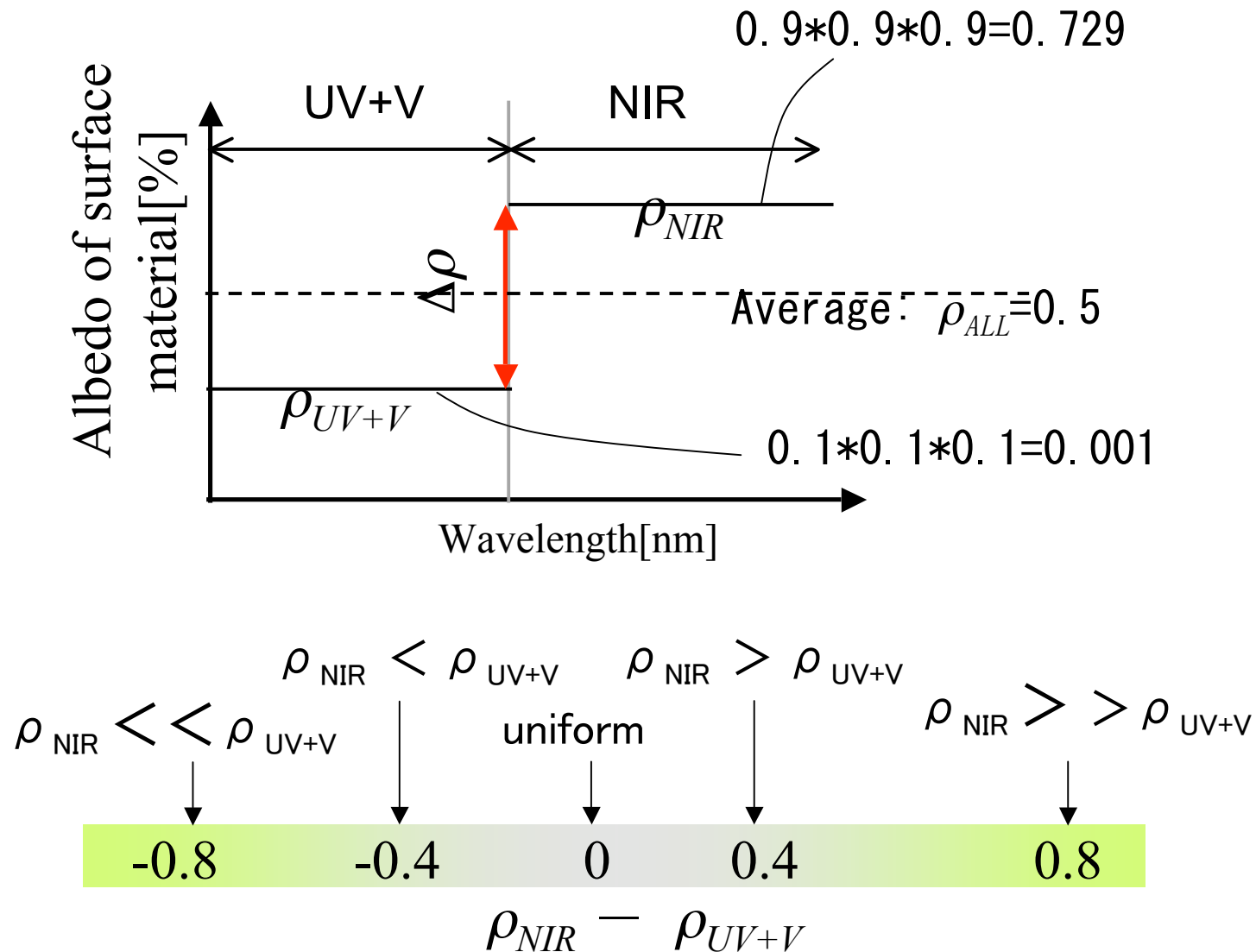
<sup>\*2</sup> The values were selected so that the buildings would be the same height for all building-to-land ratios

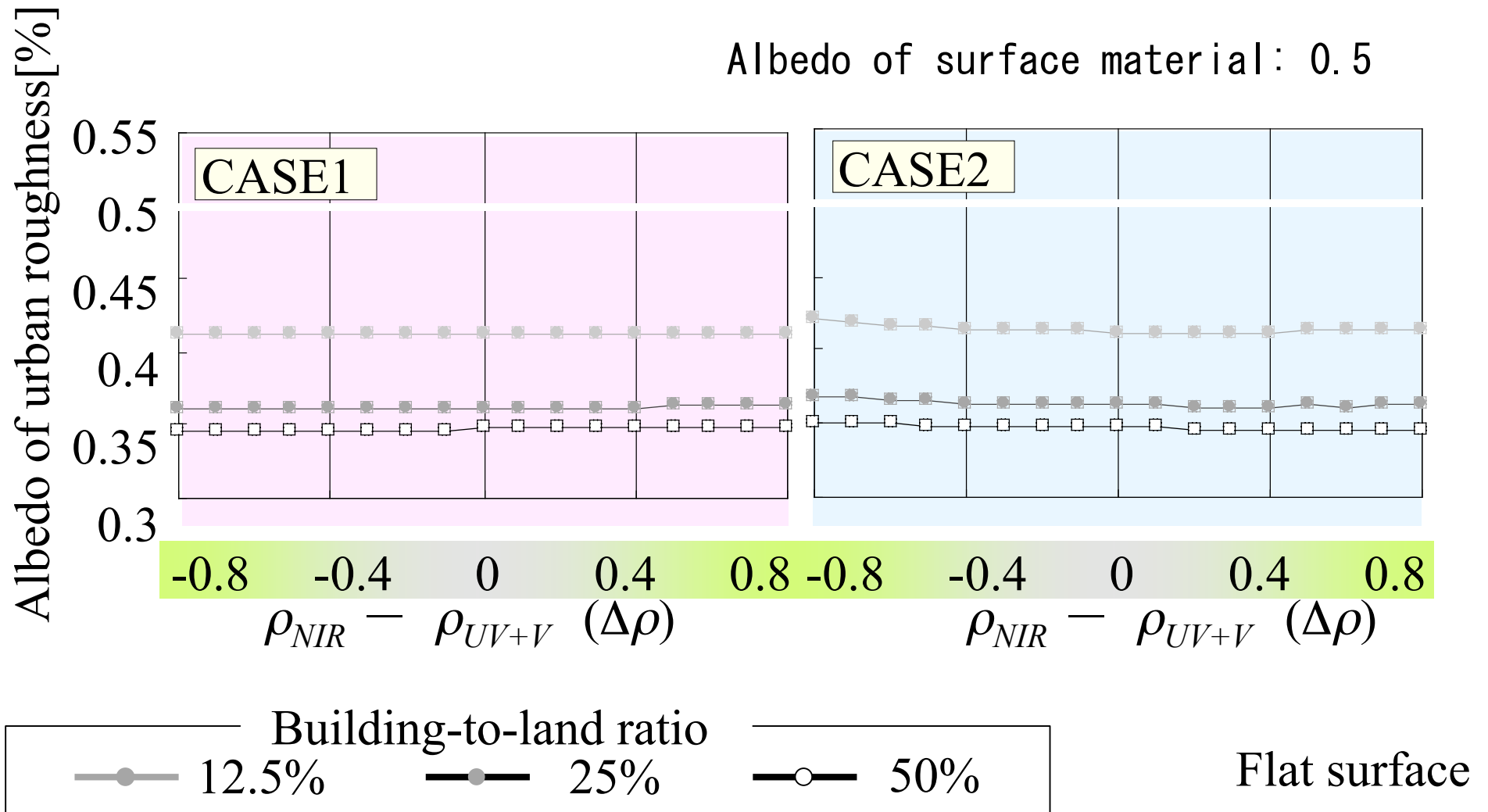
# Various materials of window film in reflectivity



透過率(耐候性試験前) 透過率(耐候性試験後)  
 反射率(耐候性試験前) 反射率(耐候性試験後)

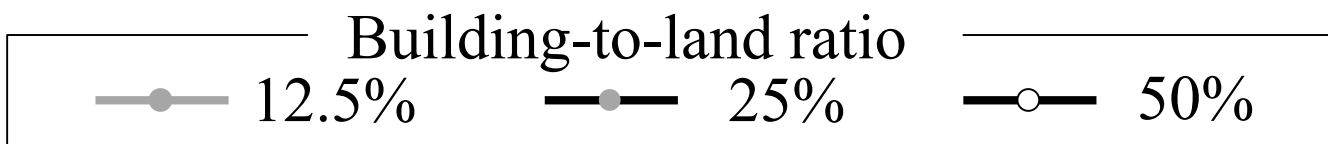
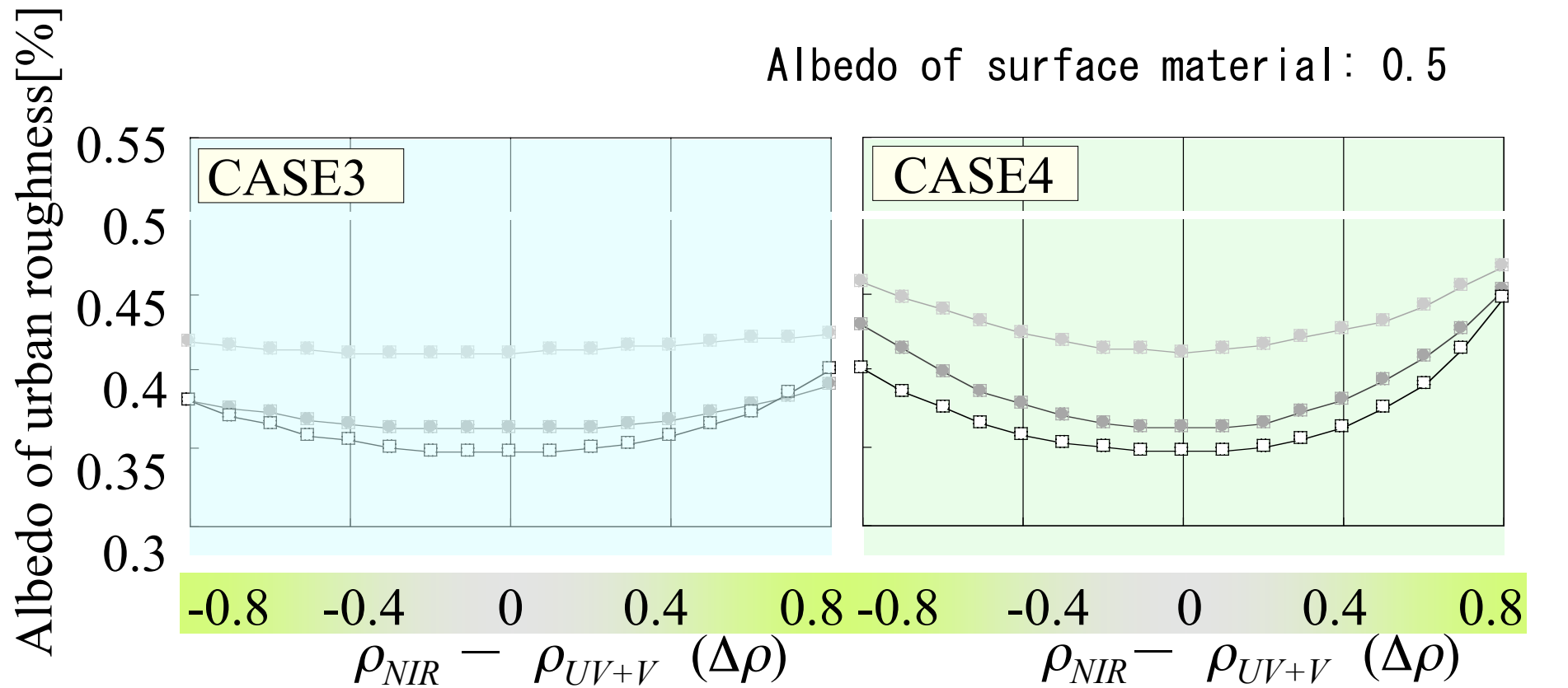
$\rho_{NIR} - \rho_{UV+V}$  ( $\Delta\rho$ ) ~an index of unevenness of spectral albedo~





Influence of spectrally selective materials on the urban albedo.  
The reflectance averaged over the entire spectrum is 0.5

CASE1, CASE2



Flat surface

Influence of spectrally selective materials on the urban albedo.  
The reflectance averaged over the entire spectrum is 0.5

CASE3, CASE4